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Growing Veggie

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ABSTRACT

Florikan is a proud partner with NASA's Veggie program, and in this presentation we will take guests through a quick tour of the current plant growth systems on the International Space Station, and our part within it. We will then expound on how our technologies aid the growth of plants in microgravity, what products are used, the benefits of fresh crops in space, results of current experiments; and how our products are used on Earth today.

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Section 1: The Task at Hand

NASA decided to reach out in mid 2013, looking for a partner in the plant nutrients field. Having a history with the organization, Florikan was invited to consult with the Veggie team. This team, headed by Dr. Gioia Massa was tasked with growing fresh vegetables in space for supplementing diet as well as enhancing life support systems. NASA is maturing Veggie technology aboard the ISS to provide future pioneers with a sustainable food supplement – a critical part of NASA's future space flights. Florikan is privileged to be a collaborator with the NASA Veggie program

1.a Definition of "Mission Assurance"

Applied/recommended techniques and lessons learned to reduce risk for those working to get to space, and those working in space.

1.b Goal of Veggie

"The Vegetable Production System (Veggie) is a deployable plant growth unit capable of producing salad-type crops to provide the crew with a palatable, nutritious, and safe source of fresh food and a tool to support relaxation and recreation." [1]

The Veggie Program On Iss With Florikan CRF… Developing A Fresh Food Sustainable System For Astronauts In Space
"Veggie - Space Plant Biology - Food Production and Astronaut Nutrition."
Florikan was selected thru a long standing relationship with NASA to provide technical support for an encapsulated controlled release nutrient product for Veggie.

Section 2: Elements of the Veggie System

2.a Veggie chamber

"The Veggie vegetable production system is a small plant growth chamber designed and built by ORBITEC (Madison, WI) to grow vegetable crops in space (Morrow et al., 2005; Morrow and Remiker, 2009). Veggie was designed to be a low mass, low power, and low crew time-requiring simple, expandable, food crop production system. After several iterations of design, development, and testing, Veggie was launched to the International Space Station (ISS) in April, 2014 in the SpaceX Dragon capsule as part of the SpaceX CRS-3 mission. Veggie was installed in the ISS Columbus module in May of 2014 into an Expedite-the-Processing-ofExperiments-to-Space-Station (ExPRESS) rack providing approximately 70 W of power to the hardware lighting and fans as well as cooling air to the lighting array" [11] A second Veggie chamber was added in September, 2017.

2.b Blue and red wavelength led light

"The hardware consists of an LED lighting array that contains red (630 nm), blue, (455 nm) and green (530 nm) LEDs and a fan which draws ISS cabin air through the hardware and expels it back to the cabin. The LED lighting can be run in manual or automatic modes and is discussed in a recent publication by Massa et al., (2016). The body of the hardware is a flexible, extensible, transparent bellows which attaches via magnets to the lighting array. The baseplate of the bellows also attaches to the lighting array via flexible support arms, and the bellows and arms allow the baseplate height below the lighting array to be fully adjustable. This enables height modification of the hardware for differing crops or for different phases of growth. The Veggie baseplate is 29.2 cm wide by 36.8 cm deep with a maximum available shoot height in an empty chamber of 47 cm." [11]

2.c Silica clay/arcillite media

In space, NASA uses in veggie production a non-swelling illite/silica clay media called Arcillite, a soilless media. Arcillite has a High CEC for Nutrient uptake. Cation exchange capacity (CEC) is the total capacity of a growing medium to hold exchangeable cations and provide essential nutrient uptake.

2.d Plant pillows, root mats

"Plant pillows are packages containing growth substrate, controlled release fertilizer, and seeds that are sent to the ISS dry and installed and hydrated on orbit. Plant pillows are designed to be passively watered from a reservoir, however other growing scenarios may utilize the Veggie facility." [4]

SECTION 3: HOW DOES CRF FIT?

3.a Consistent nutrient release over time

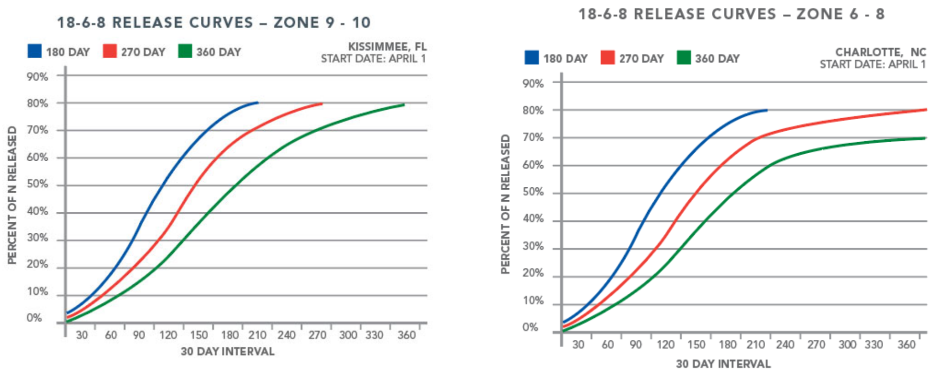

Exhibit 3.a.1 : Release curves for 18-6-8 in various soil temperature regions.

3.b Low weight for years of fertility

Ground testing was done at a dry rate of 7.5 g/L dry substrate[12]

SECTION 4: HOW DOES CRF WORK?

4.a Tortured path

1. Moisture enters the path seeks a way through, 2. Once Inside it builds pressure inside the prill. 3. This pressure sends the nutrients out to the skin to the path. The completxity of layers of the path controls the release.

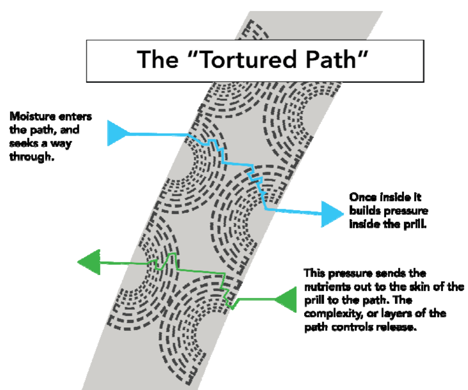

Exhibit 4.a.1 : Tourtred Path Diagram, showing how the polymer layers of the fertilizer prill work.

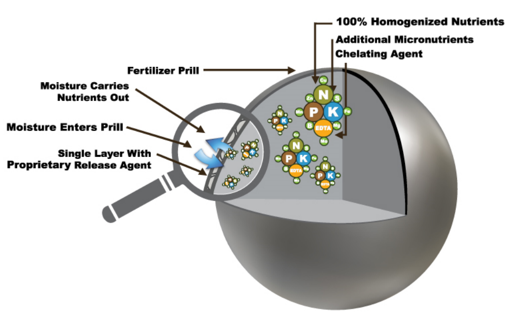

Exhibit 4.a.2 : Cutaway of prill

SECTION 5: REASONS FOR SELECTION

At NASA KSC, where failure is not an option, rigorous research is used at all points in decision making. Such was the scientific standard when it came to selection of a controlled in release fertilizer which would be used in space to grow vegetables for our astronauts on ISS.

5.a Superior product

Staged Nutrient Release (SNR) - Improved delivery of nutrients allows a farmer to tailor its nutritional program to the plant's needs over the entire crop cycle. Matching Nutrient Release with a Crop's Uptake Pattern

Why NASA selected Florikan, a result of Florikan Quality Control - Rigorous quality control of controlled release products is unmatched in the industry earning the reputation of the finest quality. A comprehensive QC and 7-day quarantine process is applied to each batch. Coated materials are tested for catastrophic failures at 30˚ C water baths for 7 days.

A Utah State University Study compared Nutricote to several other polymer coated controlled release fertilizers. They found results that would in part help NASA's Veggie researchers select Nutricote for their program.

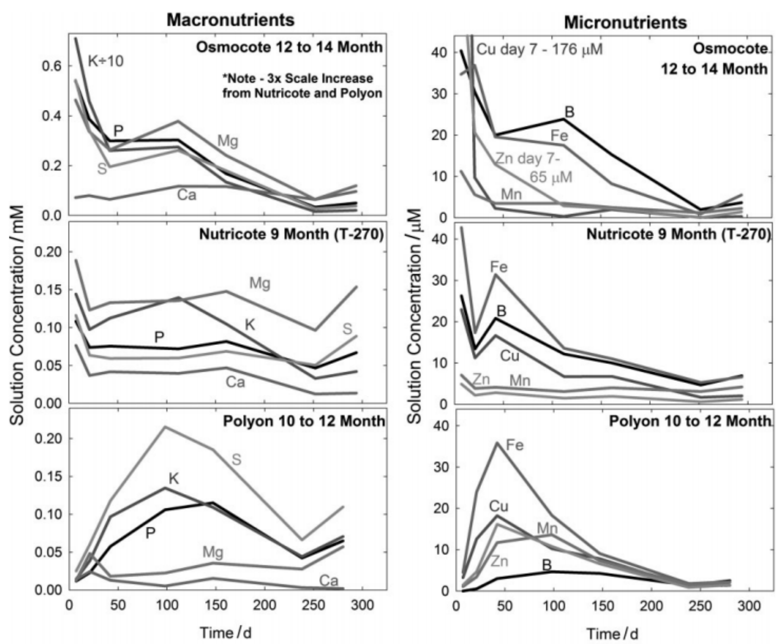

Exhibit 5.a.1[3] **:** Nutrient concentrations over time in flasks of water containing three PCF at a rate of 32.5 g PCF L–1. Each point represents fertilizer release for 1 week. For Osmocote, K values were divided by 10, and Cu and Zn were allowed to go off scale due to large values. The release of these ions from Osmocote was exceptionally rapid and required rescaling of the top left graph.[3]

"Nutricote fertilizers were the most effective at delivering steady-state release of nutrients in the mid-temperature range (20°C to 30°C). The strong effect of temperature, particularly between 30°C and 40°C, may lead to a large, early delivery of nutrients and nutrient deficiencies later (in a system with leaching). The virtual cessation of nutrient release at low temperatures suggests that all Nutricote fertilizers, including T-100, may overwinter well in cold environments as long as freezing does not result in cracking of the polymer coating. The observation of faster- and slower-release prills within a population suggests that a mix of prills with different release rates could be used to control release rate over time."[3]

5.b Solution driven innovator, honesty and credibility

Corporate Awards and Honors:

- **Space Technology Hall of Fame** - *Awarded by the Space Foundation*
- **Spinoff Magazine Selection 2018, 2017** - *Awarded by the NASA Technology Transfer Office*
- **Sterling Manufacturing Business Excellence Award – Finalist** – *Awarded by the Florida Sterling Council*
- **Florida Companies to Watch**– *Awarded by GrowFL*

- **GAL-XeONE Certified Space Certified Technology** – *Certified by the Space Foundation.*
- **Nutricote Certified Space Educational Product** – *Certified by the Space Foundation.*
- **Florikan's Educational Outreach Program is Space Certified** – Certified by the Space Foundation.
- **Gulf Guardian Award (2 Time Winner)** - *Awarded by the EPA Gulf of Mexico Program Partnership*
- **Florida Governor's Business Diversification Award** - *Awarded by Enterprise Florida*
- **Allied Associate of the Year** - *Awarded by the American Nurserymen and Landscape Association*
- **Environmental Awareness Award** - *Awarded by the Florida Nurserymen and Growers Association*
- **National New Product Award** - *Awarded By The National Society of Professional Engineers*
- **Excellence in Industry Award Manufacturer of the Year** - *Awarded by the Economic Development Committee of Sarasota County*
- **Florida Ag-Environmental Leadership Award (Finalist)** - *Awarded by the Florida Department of Agriculture*
- **Corporate Hero of Hurricane Andrew** - *Awarded by the American Red Cross*

5.c Previous history of work with NASA

The beginning of the Florikan/NASA connection starts when Florikan receives a grant for 40 hours of development time with any government agency via the National Society of Engineers – New Product Of The Year Award.

Ed Rosenthal, our companies founder, then President – decided to use the time in conjunction with NASA and the SATOP or "Space Alliance Technology Outreach Program". This paired Florikans R&D team with some of the polymer chemists in the world.

Out of this connection came a Florikote – a coating that would be a technological driver for Florikan for many years into the future.

SECTION 6: PRODUCTS SELECTED

After vigorous research NASA's veggie team decided to use two Florikan Blends: 18-6-8 for Leafy Greens and 14-4-14 for Flowering Plants and Flowering Vegetables

6.a FlorikanCRF TOTAL w/Nutricote 18-6-8

Total Nitrogen (N)	18.00%
Available Phosphate (P2O5)	6.00%
Soluble Potash (K2O)	8.00%
Magnesium (Mg)	1.20%
Sulfur (S)	4.00%
Boron (B)	0.02%
Copper (Cu)	0.05%
Iron (Fe)	0.20%
Manganese (Mn)	0.06%
Molybdenum (Mo)	0.02%

6.b FlorikanCRF TOTAL-Z w/Nutricote 14-4-14

Total Nitrogen (N)	14%
Available Phosphate (P2O5)	4%
Soluble Potash (K2O)	14%
Sulfur (S)	7.00%
Magnesium (Mg)	1.20%
Boron (B)	0.02%
Copper (Cu)	0.05%
Iron (Fe)	0.80%
Manganese (Mn)	0.06%
Molybdenum (Mo)	0.02%

SECTION 7: INITIAL SUCCESS

NASA made history in 2015 when a crop of 'Outredgeous' Red Romaine lettuce, grown in space with Florikan Controlled Release Fertilizer, was harvested and eaten by our astronauts

7.a Initial Ground Testing

With the 7.5 g/L of Florikan brand of 18-6-8 T180 day, "species varied in their growth in pillows, however most salad greens and small herbs tested grew acceptably in these confined volumes measured in plant height and chlorophyll level"[12]

"The Outredgeous lettuce grown with 7.5g/L Florikan brand of 18-6-8 T180 day , resulted in a trend to more chlorophyll and anthocyanin red pigment."[13]

7.b Veg Program Results

VEG-01A - Small Vegetable Production [8] (full results https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20150021302.pdf)

• Flew to ISS on SpaceX-3 and was installed in Columbus module in May, 2014
• Initial experiments validated capabilities using 'Outredgeous' red romaine lettuce
• Samples returned Oct., 2014

	Flight	Ground
Sample Number	3	5
Average Fresh Mass	20.61 g	15.29 g
Standard Deviation	11.66 g	9.60 g
Maximum	31.51 g	26.11 g
Minimum	8.31 g	2.81 g

Exhibit 7.a.1 [11]: *"Average fresh mass of flight and ground lettuce plants from VEG-01A. Plants were harvested, frozen at -80°C, returned to Earth, and weighed while still frozen. Standard deviations and maximum and minimum values are presented to highlight variability"[11]*

SECTION 8: DOCUMENTED BENEFITS

8.a Veggies in the space diet

"For example, in 2014, NASA began investigating whether food can be grown onboard by testing a plant growth system on the ISS. In August 2015, ISS crew members sampled red romaine lettuce grown in the system. Researchers are evaluating several varieties of leafy vegetables with the goal of selecting those with the best growth, nutrition, and taste acceptability for an ISS mission; however, it is unknown whether growing food in deep space will differ from doing so in low Earth orbit." [5]

Current NASA Crop Choices [14, 15]

• 'Outredgeous' Red Romaine lettuce
• Waldmanns green lettuce
• Mizuna mustard
• Monocot (Brachypodium distachion) & Dicot (Arabidopsis thaliana) Plants (In co-operation with the APEX program)
• Zinnia flowers
• 'Tokyo bekana' Chinese cabbage

8.b Space farming's physiological benefits

"Master's student Raymond Odeh and horticulture professor Charles Guy determined that plant-human interactions can provide astronauts the same serenity they do on Earth.

The pair make a case for "plant-mediated" therapies, which they said may balance out behavioral health, cognitive performance, and overall physical health during long-distance trips.

Astronauts spend months floating through a hostile environment, isolated and confined, unable to step outside for a breath of fresh air. Cut off from family, friends, and Netflix, the brave men and women of international space programs endure endless physical and emotional challenges. I tend toward Barry Manilow and a bar of chocolate to ease my anxieties. But not everyone can drown their sorrows at the Copacabana.

Instead, they can develop a green thumb.

Interactions with plants "provide essential benefits to the health, well-being, and longevity of people, wherever they may live," according to the study, published Oct. 2 in the journal Open Agriculture.

Odeh and Guy drive their theory home with anecdotes from astronauts who experienced the psychological impact of growing plants in space. "It was surprising to me how great [six] soybean plants looked," Peggy Whitson wrote in an email, describing her reaction to an agricultural experiment aboard the ISS in 2002.

"I guess seeing something green for the first time in a month and a half had a real effect," she continued. "From a psychological perspective, I think it's interesting that the reaction was as dramatic as it was.

"Guess if we go to Mars, we need a garden," Whitson added.

What applies to humans on Earth also applies to humans in space: Gardening is a fruitful (no pun intended) stress reliever that will no doubt follow people as we venture further from this planet."[6,7]

SECTION 9: BEYOND THE MISSION

The goal is a fresh and tasty salad on Mars, Moon or in deep space. While other NASA programs are working on getting to the Red Planet, the Agency's Veggie team is figuring out how to grow salad ingredients in space, vegetable by vegetable, with an interim goal of a salad on the International Space Station (ISS).

"Right now the astronauts are only getting fresh produce when a new supply arrives," says Gioia Massa, NASA team lead for the Veggie project at Kennedy Space Center. Veggie—the NASA program named for modular growing units designed by SNC-ORBITEC—is designed "to be kind of an astronaut garden—and an opportunity for us to do research in space."[10]

9.a Space to ground as a "Spin Off"

This technology currently powers vertical farming on the ground as well as other innovative farming technolgoies.

Vertical Farming: [9]
Current Farms - 51
Planned Farms – 220

Customer Testimonial

"Among the earliest commercial adaptors of the 14-4-14 formula was Sarasota, Florida-based Sweetgrass Farm, a fully hydroponic operation that in 2016 began the process of converting to exclusive use of Rosenthal's fertilizer system. "The plants grown with Florikan controlled-release fertilizer, which was applied only once at the beginning of the growth cycle, were healthy, vibrant, productive, and of exceptional quality," Sweetgrass owner James Demler said in a statement submitted to the U.S. Patent and Trade Office supporting Rosenthal's application for the 14-4-14 formula.

Demler also noted that his system now consists of only the controlled-release 14-4-14 fertilizer, in addition to water, seedlings, and the fibrous husks of coconuts, which he uses instead of soil or the baked ceramic NASA requires to hold the plant roots. Rosenthal worked with Demler to test seed-to-seedling yields using a nano-sized version of the 14-4-14 formula, which involves much smaller granules. "We got just about perfect yield on nearly every seed, including all the NASA varieties," Rosenthal says. "That's unheard of."[10]

Acknowledgements:

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